(12) UK Patent Application (19) GB (11) 2 155 558 A

(43) Application published 25 Sep 1985

(21) Application No 8406324

(22) Date of filing 10 Mar 1984

(71) Applicant
Rolls-Royce Limited (United Kingdom),
65 Buckingham Gate, London SW1E 6AT

(72) Inventor
Brian Barry

(74) Agent and/or Address for Service
M A Gunn,
Rolls-Royce Limited, P O Box 31, Moor Lane, Derby DE2 8BJ

(51) INT CL[4]
F01D 11/08

(52) Domestic classification
F1V 106 111 416 CAA CDD
U1S 1987 F1V

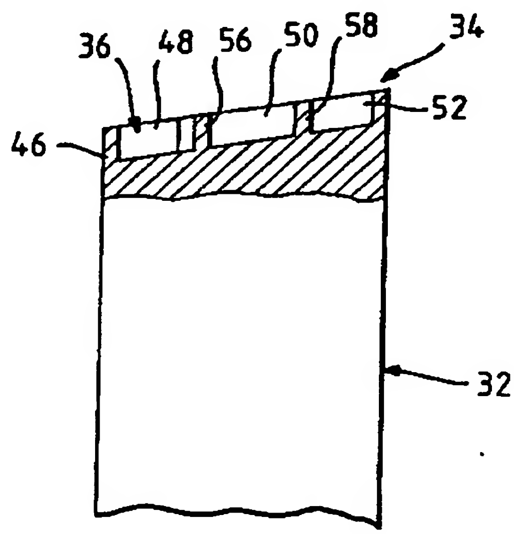
(56) Documents cited
GB 0856376

(58) Field of search
F1V

(54) Turbomachinery rotor blades

(57) An unshrouded turbine rotor blade for use particularly in gas turbine engines comprises an aerofoil 32 which has a recess at its radially outer extremity. The recess 36 is defined by a peripheral wall 46, and a number of transverse walls 56, 58 (60) extend across the recess 36 and intersect the mean chord line of the aerofoil 32 and divide the recess 36 into a number of chambers 48, 50, 52, (54). The peripheral wall 46, the transverse walls 56, 58, (60), the chambers 48, 50, 52, (54) and a cooperating stationary shroud (38) form a labyrinth seal to control a leakage flow of hot gases between the radially outer extremity of the aerofoil 32 and the shroud (38). The optimum reduction in the leakage flow of hot gases between the radially outer extremity of the aerofoil and the shroud is achieved when the transverse walls are positioned substantially perpendicular to the direction of the leakage flow.

Fig. 4.



GB 2 155 558 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

2155558

1/4

Fig. 1.

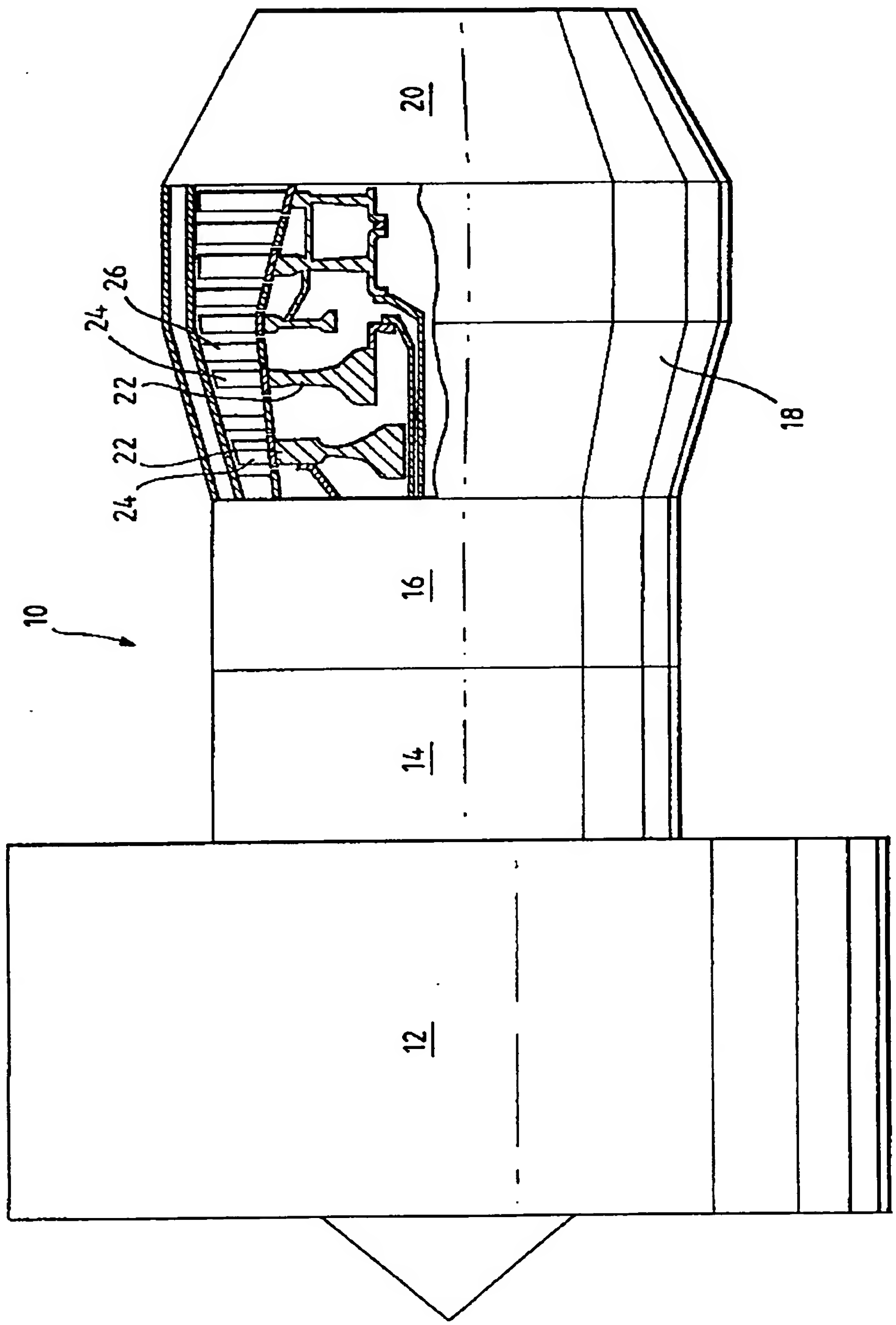


Fig. 2.

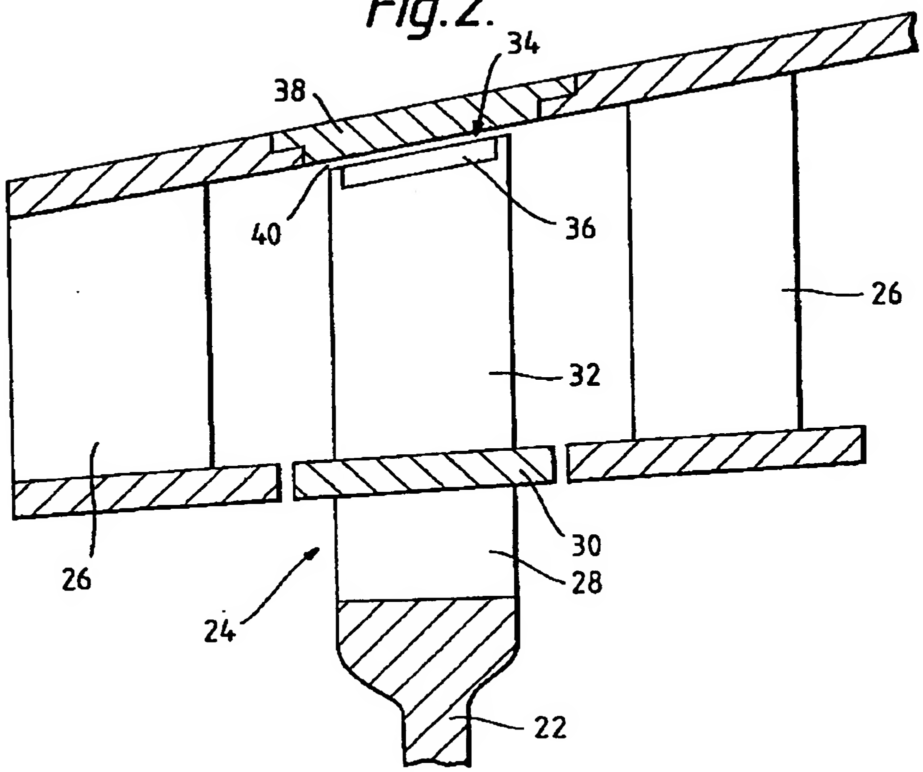


Fig. 3.

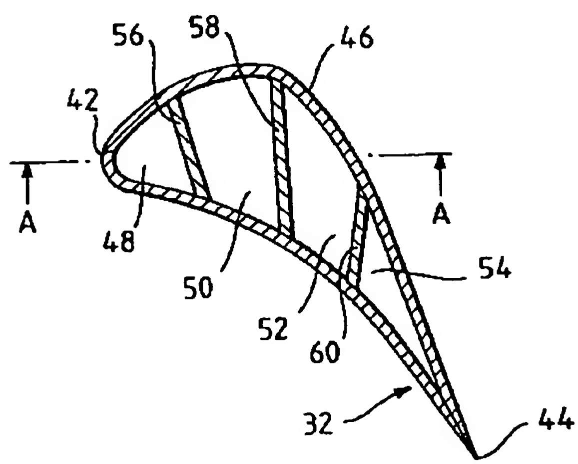


Fig.4.

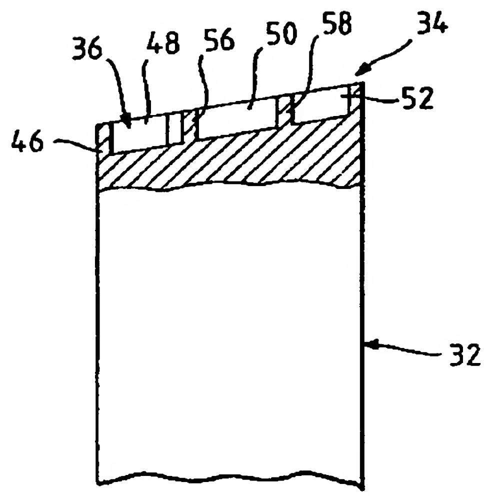


Fig.5.

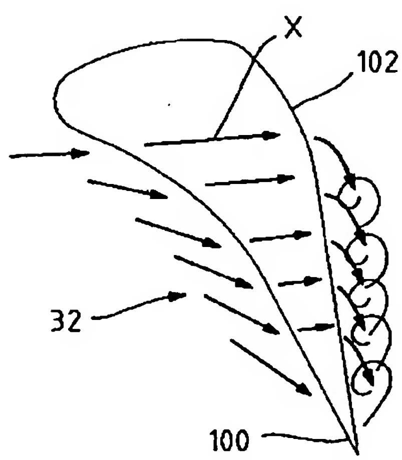


Fig.6.

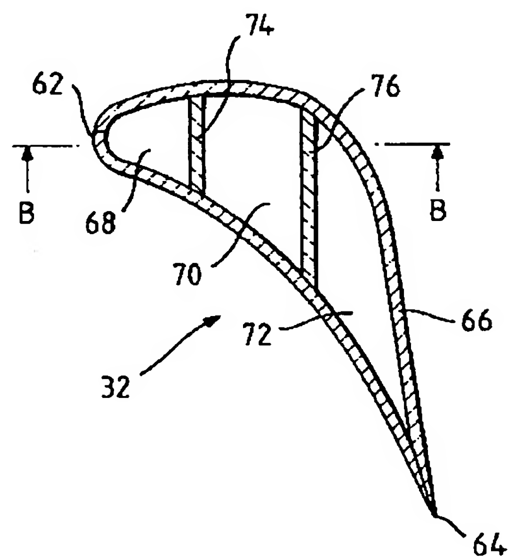


Fig.7.

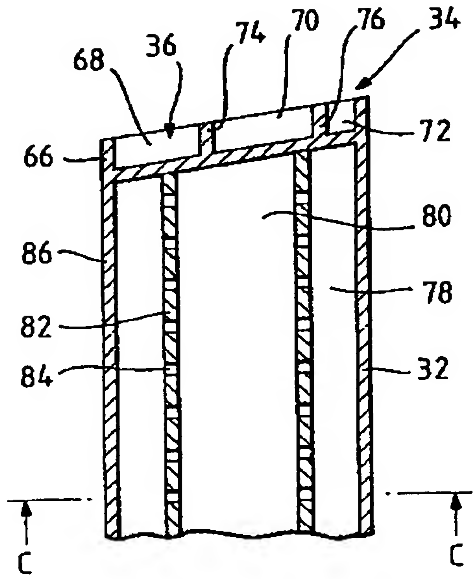
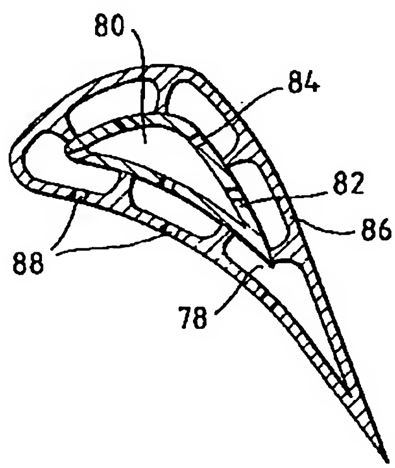


Fig.8.



SPECIFICATION

Improvements in or relating to turbomachinery rotor blades

The present invention relats to turbomachinery rotor blades and in particular to tip recesses in turbo-machinery rotor blades for use in a gas turbine engine.

The efficiency of each rotor stage in a gas turbine engine is dependent upon the amount of energy transmitted into the rotor stage, and this is limited particularly in unshrouded blades by any leakage flow of working fluid i.e. air or gas across the tips of the blades of the rotors. By controlling the leakage flow of air or gas across the tips of the blades it is possible to increase the efficiency of each rotor stage.

The present invention seeks to provide a turbomachinery blade that will reduce the leakage flow of air or gas across the tip of unshrouded blades.

Accordingly the present invention provides an unshrouded turbine rotor blade including an aerofoil portion, the radially outer extremity of the aerofoil portion having a recess defined by a peripheral wall, at least one transverse wall extending across the recess and intersecting the mean chord line forming at least two chambers, the peripheral wall, the wall extending across the recess, the chambers and a cooperating stationary shroud forming a labyrinth sea to control a leakage flow of hot gases between the radially outer extremity of the aerofoil and the shroud.

The at least one wall extending across the recess and intersecting the mean chord line is substantially perpendicular to the direction of leakage flow of hot gases between the radially outer extremity of the aerofoil and the shroud.

The aerofoil may have two or three walls extending across the recess in the radially outer extremity of the aerofoil.

The aerofoil may have an internal arrangement of passages for the flow of cooling air.

The aerofoil may be hollow and comprise an outer wall which defines the shape of the aerofoil; an inner wall which divides the hollow aerofoil into an inner and an outer chamber, the inner wall is spaced from the outer wall by a plurality of lands which extend from the outer wall, the inner wall has a plurality of apertures which allow cooling air in the inner chamber to flow into the outer chamber and to impinge upon the inner surface of the outer wall.

The outer wall of the aerofoil has a plurality of apertures to allow cooling air in the outer chamber to flow onto the outer surface of the outer wall.

Alternatively the aerofoil may be substantially solid.

The invention will be described more fully with reference to the accompanying drawings in which:—

Figure 1 is a diagrammatic view of a gas turbine engine which is partially cut away to show the turbine section.

Figure 2 is an enlarged cross-sectional view of the turbine section shown in Fig. 1.

Figure 3 is an enlarged view of one embodiment of the tip of the turbine rotor blade shown in Fig. 2.

Figure 4 is a cross-section along the line A–A in Fig. 3.

Figure 5 shows to an enlarged scale the direction of leakage flow across the tip of the turbine rotor blade in Fig. 2.

Figure 6 is an enlarged view of an alternative embodiment of the tip of the turbine rotor blade in Fig. 2 and

Figure 7 is a cross-section along the line B–B in Fig. 6.

Figure 8 is a cross-section along the line C–C in Fig. 7.

A gas turbine engine 10 as shown in Fig. 1 comprises in flow series a fan 12, a compressor 14, a combustion system 16, a turbine section 18 and a nozzle 20. The turbine section 18 comprises a number of rotors 22 and stator vanes 26, each rotor 22 has a plurality of turbine blades 24 which extend radially therefrom.

Fig. 2 shows one of the rotors 22 and one of the turbine blades 24 secured thereto, and the adjacent stator vanes 26. The turbine blade 24 comprises a root 28, a platform 30 and an aerofoil 32, the root 28 and aerofoil 32 are secured to opposite faces of the platform 30. The aerofoil 32 has a tip 34 at the end remote from the platform 30, and the tip 34 has a recess 36. A shroud 38 extends circumferentially around and is spaced from the rotor 22 and the radially extending turbine blades 24 by a clearance gap 40.

Figs. 3 and 4 show the recess 36 in the tip 34 of the aerofoil 32. The aerofoil 32 has a leading edge 42 and a trailing edge 44 respectively and a peripheral wall 46 at the radially outer extremity of the aerofoil defines the recess 36. The recess 36 is divided into a number of chambers 48, 50, 52 and 54 respectively by a number of walls 56, 58, 60 which extend across the recess 36 and intersect the mean chord line of the aerofoil.

Fig. 5 shows the direction of leakage flow across the tip 34 of a turbine blade 24. In turbines with unshrouded turbine rotor blades a small portion of the working fluid flowing through the turbine tends to migrate from the concave pressure surface 100 of the aerofoil to the convex suction surface 102 of the aerofoil through the clearance gap 40 between the tip of the aerofoil and the stationary shroud. This leakage flow occurs because of a pressure difference which exists between the pressure and suction surfaces of the aerofoil, and the leakage flow also causes flow disturbances to be set up over a large proportion of

the height of the aerofoil which increases losses of efficiency of the turbine.

Figs. 6, 7 and 8 show the recess 36 in the tip 34 of an aerofoil 32 which has a different number of walls which extend across the recess and also show the internal construction of the aerofoil 32. The aerofoil has a leading and trailing edge 62 and 64 respectively, and a peripheral wall 66 at the radially outer extremity of the aerofoil defines the recess 36. The recess 36 is divided into a number of chambers 68, 70 and 72 respectively by a number of walls 74 and 76 which extend across the recess 36 and intersect the mean chord line of the aerofoil. The internal construction of the aerofoil is shown and comprises in this particular embodiment an inner and outer chamber 80 and 78 respectively which are separated from each other by an inner wall 82. The inner wall 82 has a number of apertures 84 which connect the inner and outer chamber 80 and 78 respectively, so that cooling air in the inner chamber 80 may flow through the apertures 84 and impinge on the inner surface of the aerofoils outer wall 86 to aid cooling. Other types of cooling may be provided, such as apertures 88 in the outer wall of the aerofoil to provide film cooling of the outer surface of the outer wall.

A turbine blade 24 as shown is generally manufactured by casting the root, platform and outer wall of the aerofoil, and the inner wall 82 is brazed to a number of lands which extend from the inner surface of the outer wall 86. The tip 34 of the aerofoil is then secured to the radially outer extremity of the aerofoil by brazing or other metallurgical means or by mechanical means.

In operation air enters the gas turbine engine 10 and flows through and is compressed by the fan 12 and the compressor 14. Fuel is burnt with the compressed air in the combustion system 16, and hot gases produced by the combustion of the fuel and the air flow through the turbine section 18 and the nozzle 20 to atmosphere. The hot gases drive the turbines which in turn drive the fan 12 and compressors 14 *via* shafts.

The turbine section 18 comprises stator vanes 26 and rotor blades 24 arranged alternately, each stator vane 26 directs the hot gases onto the aerofoil 32 of the rotor blade 24 at the optimum angle. Each rotor blade 24 takes kinetic energy from the hot gases as they flow through the turbine section 18 in order to drive the fan 12 and the compressor 14.

The efficiency with which the rotor blades 24 take kinetic energy from hot gas determines the efficiency of the turbine, and this is partially dependent upon the leakage flow of hot gases between the tip 34 of the aerofoil 32 and the circumferentially extending shroud 38. By controlling the leakage flow between the tip 34 of the aerofoil 32 and the circumferentially extending shroud 38 the efficiency of the turbine can be improved.

The leakage flow across the tip 34 of the aerofoil 32 can be reduced by providing a recess 36 in the tip 34 of the aerofoil 32, and this recess 36 has a number of walls 56, 58 and 60 which extend across the recess 36 and intersect the mean chord line of the aerofoil to form a number of chambers 48, 50, 52 and 54 as shown in Figs. 3 and 4. The walls 56, 58 and 60 are positioned substantially perpendicular to the direction of the leakage flow in order to obtain the optimum reduction in the leakage flow.

The walls 56, 58 and 60 and the peripheral wall 46 form a labyrinth seal with the circumferentially extending shroud 38. It is believed that trapped vortices are set up in each of the chambers 48, 50, 52 and 54 and these trapped vortices reduce the leakage flow between the tip 34 of the turbine rotor blade 24 and the shroud 38.

The leakage flow must pass over several of the walls 56, 58 and 60 which extend directly across the flow path, and the leakage flow is reduced in each of the chambers 48, 50, 52 and 54 in turn by the associated vortices trapped in each of these chambers.

Similarly the walls 74 and 76, and the peripheral wall 66 form a labyrinth seal with the circumferentially extending shroud 38 in Figs. 6 and 7, and the trapped vortices set up in chambers 68, 70 and 72 reduce the leakage flow between the tip 34 of the turbine rotor blade 24 and the shroud 38.

The chambers formed in the recess in the tip of the aerofoil must be sufficiently large for one or more trapped vortices to be set up in each chamber. For example if a honeycomb type tip is used with a large number of chambers a reduction in the leakage flow between the tip of the aerofoil and the shroud will not be achieved because vortices will not be set up in the chambers of the honeycomb material.

The recess in the tip of the aerofoil and the walls extending across the recess may be applied to solid turbine blades or to turbine blades having an arrangement of internal cooling passages.

CLAIMS

1. An unshrouded turbine rotor blade including an aerofoil portion, the radially outer extremity of the aerofoil portion having a recess defined by a peripheral wall, at least one transverse wall extending across the recess and intersecting the mean chord line, forming at least two chambers, the peripheral wall, the wall extending across the recess, the chambers and a cooperating stationary shroud forming a labyrinth seal to control a leakage flow of hot gases between the radially outer extremity of the aerofoil and the shroud.

2. An unshrouded turbine rotor blade as claimed in claim 1 in which the at least one transverse wall extending across the recess and intersecting the mean chord line is substantially perpendicular to the direction of leakage flow of hot gases between the radially outer extremity of the aerofoil and the shroud.

3. An unshrouded turbine rotor blade as claimed in claim 1 or claim 2 in which the aerofoil has two walls extending across the recess in the radially outer extremity of the aerofoil.

4. An unshrouded turbine rotor blade as claimed in claim 1 or claim 2 in which the aerofoil has three walls extending across the recess in the radially outer extremity of the aerofoil.

5. An unshrouded turbine rotor blade as claimed in any of claims 1 to 4 in which the aerofoil has an internal arrangement of passages for flow of cooling air.

6. An unshrouded turbine rotor blade as claimed in claim 5 in which the aerofoil is hollow and comprises an outer wall which defines the shape of the aerofoil, an inner wall which divides the hollow aerofoil into an inner and an outer chamber, the inner wall is spaced from the outer wall by a plurality of lands which extend from the outer wall, the inner wall has a plurality of apertures which allow cooling air in the inner chamber to flow into the outer chamber and to impinge upon the inner surface of the outer wall.

7. An unshrouded turbine rotor blade as claimed in claim 6 in which the outer wall of the aerofoil has a plurality of apertures to allow cooling air in the outer chamber to flow onto the outer surface of the outer wall.

8. An unshrouded turbine rotor blade as claimed in any of claims 1 to 4 in which the aerofoil is substantially solid.

9. An unshrouded turbine rotor blade substantially as herein described with reference to the accomapnying drawings.

10. A turbine rotor comprising a plurality of turbine rotor blades as claimed in any of the preceeding claims.

11. A gas turbine engine comprising at least one turbine rotor as claimed in claim 10.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1985, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

This Page is Inserted by IFW Indexing and Scanning Operations and is not part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☑ FADED TEXT OR DRAWING
- ☑ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☑ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: ______________________

IMAGES ARE BEST AVAILABLE COPY.
As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.